JULY 1956 REPORT 135

PRENATAL DEVELOPMENT

Range Cattle Production, 2

A Literature Review

By
C. B. ROUBICEK, R. T. CLARK, P. O. STRATTON
and O. F. PAHNISH

A contribution from the W-1 Regional Research Project, "Improvement of Beef Cattle through the Application of Breeding Methods," in which the Western States — Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming and the Territory of Hawaii — are cooperating with the Agricultural Research Service, United States Department of Agriculture.

Published by
Agricultural Experiment Station
University of Arizona
Tucson

RANGE CATTLE PRODUCTION

A Literature Review

Section II

PRENATAL DEVELOPMENT

Carl B. Roubicek
Animal Science Department
University of Arizona

R. T. Clark
Coordinator, Beef Cattle Breeding Research
United States Department of Agriculture
Denver, Colorado

Paul O. Stratton
Animal Production Department
University of Wyoming

O. F. Pahnish
Animal Science Department
University of Arizona

PRENATAL DEVELOPMENT

Ovulation

The time and manner of follicular development varies greatly in the same individual and between individuals. The majority of the follicles reach a diameter of 16 to 19 mm. before rupture, but they may rupture at 10 mm. (115).

The two major factors influencing ovarian weights were the age of the animal and the presence of a functional corpus luteum. Additional minor influences included breed, the more frequent occurrence of the corpus luteum in the right ovary, the effect of pregnancy on the weight of the ovary, and individuality (54). The average weight of the ovaries of the pregnant cattle exceeded that of the nonpregnant animals by approximately 10 percent. The right ovaries exceeded the left ovaries in weight by 17 percent, and the corpus luteum was present in that ovary in 54 percent of the heifers. The corpora lutea in this experiment ranged in weight from 2.83 to 6.57 gm. between 25 and 45 days, and showed a slight though constant increase in average weight during this stage of pregnancy. They varied in shape from irregularly round to irregularly oval.

The time of ovulation in females in relation to the onset of heat has been reported as 24 to 65 hours (114)(165)(115)(39)(22).

Variations in total N, dry matter, viscosity, and flow-elasticity of bovine cervical mucus have been studied during the estrous cycle (140). Total N, dry matter, and viscosity reach maximum values at about the time of estrus. Flow-elasticity shows a marked maximum.

Mammalian ova which have migrated into the oviduct are surrounded by a sphere of follicular cells. The mechanism whereby the ovum is freed from these cells to promote fertilization is quite obscure. Preparations rich in hyaluronidase, such as testicles, have a very pronounced effect in dispersing the follicular cells surrounding the ova. It appears that hyaluronidase itself is responsible for this effect, an indispensable step in fertilization (53).

The color of the corpus luteum of estrum is at first a light brown, about the 7th day an old gold, by the 14th day a bright golden yellow, by the 20th day an orange or yellowish orange, eventually changing to a bright brick-red. This color change is associated with the quantity and character of the lipoid in the lutein cells (115). The length of the functional life of the corpus luteum in the absence of pregnancy is approximately 16 to 18 days (155). In some areas a reported common occurrence is for cows to come into estrus during pregnancy (124).

Prenatal Growth

The egg requires about 96 hours to traverse the uterine tube (66).

The attachment of the bovine embryo to the walls of the uterus by means of the union of the fetal and maternal cotyledons is a gradual process beginning about the 36th day of pregnancy in the area closest to the embryo and gradually spreading throughout the pregnant horn, the body of the uterus, and a large part of the nonpregnant horn (117)(54).

In the initial stage, the fetal trophoblast erodes the epithelial cells covering the surface of the maternal cotyledons some time prior to the 25th day of gestation. Between 30 and 35 days of pregnancy the surface of the maternal cotyledons became wavy or undulating, and shallow pockets containing fetal tissue began to appear. During this stage the connective tissue of the maternal cotyledons responded to the stimulus of the fetal trophoblast by outgrowth from the surface of the cotyledon to form semicrypts lined with fetal tissue.

After the 36th day, a continuation of the ingrowth of the trophoderm accompanied by an intricate branching of the fetal villi with a corresponding growth of the maternal cotyledons to form additional crypts resulted in the formation of placentomes and an increasingly firmer attachment of the fetal membranes to the wall of the uterus. Attachment in the bovine is a graded process and the steps described above are repeated again and again at greater distances from the embryo as gestation advances.

The indeciduate cotyledonary placenta of the cow is syndesmochorial in type, and the cells lining the maternal crypts are of fetal origin. The epithelial cells, which normally cover the surface of the maternal cotyledons in nonpregnant cattle, disappeared prior to the 26th day of gestation and did not reappear during the course of this experiment. The single layer of pale-staining cells noted in the pockets on the surface of the maternal cotyledons and surrounding the outgrowths of maternal connective tissue between 30 and 35 days were identical in appearance with many cells of the adjacent fetal trophoblast. Although these cells appeared somewhat more cuboidal in lining the semicrypts, they still retained their distinguishing characteristics of fetal tissue. In the maternal crypts, especially during the third and fourth months of gestation, these lining cells were flattened even more to present a squamous appearance with a characteristic chainlike pattern of nuclei, but there can be little doubt that they represent the end point of the chain of events described earlier. Thus, the placental barrier in the cow is syndesmochorial, and the maternal and fetal blood streams are separated by the following tissues: maternal--the endothelium of the capillaries and the connective tissue of the walls of the crypts; fetal--the fetal cells lining the maternal crypts, the cells of the villi, embryonic connective tissue within the villi, and the endothelium of the fetal capillaries.

During the preimplantation period the embryo receives its nourishment entirely from the uterine secretions (118). Estrogenic substances have been reported to tube-lock the ova if used at the time of fertilization (162).

A cross-section of the uterine wall of the cow shows about the same construction as is found in other species: first, the endometrium; second, the vascular bed; third, the muscles; and, fourth, the serous coat (93).

The endometrium or lining of the bovine uterus is made up of (a) specialized nonglandular areas, called cotyledons or caruncles, raised slightly above the surface of the mucosa, and (b) the intercotyledonary areas, which contain abundant long tubular uterine glands. During the first month of pregnancy there is a vascularization of the maternal cotyledons in preparation for the attachment of the fetal membranes. This vascularization is similar to but more extensive than that which occurs during the estrous cycle. In older cattle, the blood vessels at the base of the cotyledons are especially well developed and numerous. The uterine glands, which are abundant in the middle and deep zones of the intercotyledonary endometrium, are surrounded by numerous blood and lymph vessels and appear to be actively secreting uterine milk during the early stages of pregnancy (54).

Regional differences in the genital tract were associated with changes in the sexual cycle and during pregnancy. During the first part of pregnancy the cervical changes are slight, both in the epithelium and in the stroma. The stroma is very dense and contains a few blood vessels. At about the 85th day of pregnancy the superficial epithelial cells are definitely increased in height and from then on to near the end of pregnancy these mucus-secreting cells may be seen in all stages of activity (34).

In the development of the fetal placenta, the chorionic villi grow out as buds from the chorionic epithelium toward the maternal placental areas and ultimately implant themselves in the developing placental crypt. The growing villus apparently irritates the uterine tissue and coincident with the growth of the villus the uterine mucosa grows up around the villus, thus forming the uterine crypt. Apparently, as a rule the uterine epithelium is eroded by the epithelium of the chorionic bud. Later this is repaired and the crypt becomes lined with epithelium. The development of the chorionic villi is a continuous process throughout the period of pregnancy. New chorionic buds may be seen developing at any stage of pregnancy (65).

Should conception occur, the entire uterus continues to hypertrophy. The uterine glands continue secretion, with some decrease in activity in late gestation. The uterine part of the placentome is an outgrowth from the stratum compactum of the caruncle. It forms crypts which surround the villi of the fetal cotyledon. A low syncytium of undetermined origin covers the septa of the caruncular crypts everywhere except on their distal ends. This syncytium contains a lipid, and it forms a complete alkaline phosphatase barrier between maternal and fetal bloods (159).

The trophoblast of the villi is an irregular syncytium in which are characteristic giant cells. The giant cells react heavily for alkaline phosphatase and glycoprotein. The trophoblast between the bases of the villi is predominantly irregular, tall, columnar cells. These cells absorb histotroph from the space which separates them from the distal ends of the caruncular septa. Red blood corpuscles absorbed by the columnar trophoblast give rise to yellow-brown, lipoprotein pigment deposits.

The columnar trophoblast of the intercotyledonary chorion resembles that seen in the placentome; however, acetone-soluble lipid granules were definitely identified here.

At the beginning of the second month of pregnancy, the bovine chorion consists essentially of a single layer of plasmodial cells, the trophoblast, which is vascularized by allantoic mesoderm containing small arterioles and abundant capillaries in the areas closest to the embryo (54). The majority of the cells of the trophoblast are irregularly round or oval with variously sized nuclei containing prominent nucleoli, whereas the highly granular cytoplasm suggests the presence of ingested material. Large, round binucleate cells are quite common.

At irregular intervals, small sections of trophoderm exhibit tall, narrow cells with lightly stained cytoplasm and small nuclei at varying heights from extreme basal positions to the top of the cells, thus giving a pseudostratified appearance.

The development of the fetal cytoledons begins on the ventral surface of the chorion closest to the embryo and at those points in contact with maternal cotyledons. At 25 to 28 days, no fetal villi were noted on the sections of chorion. Between 30 and 35 days, villi occurred on samples of chorion selected from areas closest to the embryo.

Between 35 and 45 days, fetal cotyledons were easily recognized, the mesodermal lining extended out into the stalk, and the villi were beginning to branch. After the 45th day, the further development of the fetal cotyledons was essentially a growth phase with vascularization and extensive branching of the villous processes (54).

At all times during gestation there is some intercaruncular epithelium on the uterus. This epithelial layer is partially destroyed at all stages between the 21st and the 260th days of gestation (73). Various stages of epithelial destruction may be seen at any time during the period of gestation. The placentomal relationship in the caruncular areas is epitheliochorial. The caruncle develops by an overgrowth of the tissues of the lamina propria pushing the epithelium toward the uterine lumen. The connective tissue is invaded by cords of epithelial cells from the surface which forms pockets or canals in the caruncle. These pockets are invaded by and filled with tissues of the chorionic trophoderm.

Alkaline phosphatase as determined by the Gomori method was present in substantial amounts in both the endometrium and the chorion during the early months of pregnancy (54). The enzyme was present in the endothelium of the uterine blood vessels, in the uterine glands and their secretions, and just below the surface of the endometrium in both the cotyledons and in the intercotyledonary areas. All samples of chorionic tissue were positive for alkaline phosphatase, and principal site of the enzyme being in the larger cells and especially the binucleate cells of the trophoblast and the fetal villi. The cells lining the maternal crypts had the same reaction to the test for alkaline phosphatase as cells in the fetal villi.

Herzheimer's solution failed to demonstrate the presence of neutral fats in the bovine endometrium during these stages of pregnancy, but all sections of chorion gave a positive reaction, especially at the base of the trophoblastic cells (54).

All sections of maternal endometrium, both cotyledons and intercotyledonary areas, gave a positive reaction to the Schultz test for cholesterol; this was also true for all chorion samples that were tested (54).

Although the typical corpus luteum of pregnancy appeared to have a deep orange color, it ranged from deep yellow to cocoa brown. As the lutein cells increased in size and plumpness between 25 and 45 days of pregnancy, the open structure that distinguished the early corpora lutea of pregnancy became more compact with a marked increase in vascularity and some increase in connective tissue (54).

Alkaline phosphatase was present in substantial amounts in the endometrium, chorion, and corpus luteum during the early months of pregnancy (55). Neutral fats could not be demonstrated in the endometrium of heifers pregnant 25 to 35 days. All sections of the chorion, however, gave a positive reaction especially at the base of the trophoblastic cells. All sections of the endometrium and chorion showed presence of cholesterol.

The average measurements of the cervices of 22 virgin heifers were 2.3 inches in length and 0.75 inches in diameter. For mature cows the average was 3.4 inches in length and 1.6 inches in diameter (76).

The thyroid and parathyroid glands function very early in embryonic development (148). The thyrotropic action of hypophysis is also manifest very early. Apparently, the characteristic relationship between hypophysis and thyroid establishes itself simultaneously with histological differentiation of the glands. The function of endocrine glands during fetal life is insignificant only under optimal environmental conditions in which the fetal organism develops. As soon as deviation from the optimum occurs, the endocrine system can be mobilized as one of the most important regulations of vital functions in the organism.

The two-celled stage in the bovine was recovered 52 hours after copulation (165). Measurement data of bovine embryos indicate that tables of normal growth for prenatal development can probably be established (119). There is good agreement among research workers on prenatal growth (119)(149)(54)(166).

In a study of allometric growth of the forelimb in cattle, an opposite allometric course in fetal and postnatal development was noted (126). This inversion does not occur after birth and might occur at birth or before birth. The moment of this inversion might be very important in determining subsequent developmental breed differences.

Fetal Composition

The amount of nutrients necessary to develop the bovine fetus is so small that it cannot be measured by ordinary methods (49). The total weight gain of pregnant animals is greater than is the weight of the fetus including fetal membranes, etc. (52). The weight increase noted for pregnant mice is also noted for pseudopregnant animals (52)(71). This weight gain is not noted for as long a period in the pseudopregnant animals, but in any case it would appear that the fetus and its membranes are responsible only in part, if at all, for the increased growth rate of pregnant animals.

Progesterone apparently does not stimulate appetite. If the ovary is indirectly involved it may be by depressed estrogen secretion following mating, inasmuch as appetite is increased following castration (71).

Beef cows receiving a carotene allowance equivalent to 60 µg. per pound of body weight daily were unable to maintain liver stores or plasma vitamin A levels during the last 6 months of gestation. When the carotene allowance was increased to 333 µg. during lactation, liver stores and plasma vitamin A were increased (6). Under orginary range conditions the intake of carotene may be adequate for gestation (158) although there the vitamin A in the plasma and liver of the calf was closely associated with the carotene intake of the dam during lactation and is also influnced by the liver stores of the cow at parturition (See Table IV)(6)(20).

TABLE I

Measurements of Bovine Fetuses by Age (166)

Age of Fetus (days)	Weight (gm.)	Forehead-rump length (cm.)	Head Length (cm.)	Head Breadth (cm.)	Forearm Length (cm.)
45	2.77	3.08	.5	.825	.475
50	4.94	3.85	.6	.850	.500
60	13.78	6.60	1.15	1.450	1.15
70	37.25	9.40	3.3	2.0	1.90
90	159.8	16.4	5.0	3.3	2.70
100	317.2	18.8	6.0	3.9	3.30
120	820	27.1	8.4	5.0	5.00
140	1807	32.6	11.0	6.1	7.20
160	3562	43.7	13.2	7.5	9.10
185	6685	54.0	16.6	8.3	13.20
200	10433	58.5	18.2	9.4	18.50
230	18144	73.0	18.5	10.2	20.00
260	31298	87.0	23.0	11.5	23.00

TABLE II

Weights and Measurements of Embryos between 25 and 45 Days of Pregnancy (54)

Age (days)	Weight (gm.)	Crown-Rump Length (cm.)	Contour Length (cm.)
25-28	0.052	0.725	1.711
35-40	0.875	2.025	4.188
42-43	2.298	2.977	6.290

TABLE III

Relation between Length and Age of Bovine Fetus (152)

Weeks of Pregnancy	Length, Forehead to Base of Tail (cm.)
4	0.8
8	5.4
12	13.3
16	24.5
20	39.0
24	51.0
28	68.0
32	80.0

TABLE IV

Relationship of Maternal and Fetal Vitamin A Content (20)

Normal Intake		Restricted Intake	
Liver of Dam (I.U./gm.)	Liver of Fetus (I.U./gm.)	Liver of Dam (I.U./gm.)	Liver of Fetus (I.U./gm.)
224.7	6.2	120.8	2.7
175.8	6.1	94.0	0.0

TABLE V

Composition of Amniotic Fluid and Placenta of the Bovine (49)

	Amniotic Fluid	Placenta
Weight (lbs.)	32.7	18.3
Water (%)	95.9	85.6
Fat (%)	0.92	0.92
Protein (%)	3.36	12.20
Ash (%)	0.65	0.89

The pH of the amniotic fluid varies from 7.0 to 7.4 with an average value of 7.12 (104).

The thyroid helps regulate the conversion of carotene to vitamin A. In view of the importance of vitamin A for the maintenance of pregnancy, the possibility must be considered that a hypothyroid state combined with a low intake of vitamin A could result in abortion, or dead or weak offspring (116).

Tocopherol concentrations in the blood serum of dairy cows restricted to typical barn rations decreased slowly during the terminal month of pregnancy. The decline generally became more pronounced within a few days before parturition and reached a minimum level the second day postpartum, after which a gradual but continuous rise ensued (105). A seasonal trend has also been noted for the vitamin D content of maternal blood plasma, and blood plasma and liver of the newborn calf (48).

In a study of the distribution of "trace elements" in the newborn calf, the following trace elements were detected in various organs and tissues (137): aluminum, barium, boron, chromium, cobalt, lead, manganese, molybdenum, nickel, silver, strontium, tin, titanium, vanadium, and zinc. The following elements were not detected in any of the tissues or organs: arsenic, antimony, beryllium, bismuth, cadmium, cesium, lanthanum, lithium, thorium, tungsten, yttrium, and zirconium. Zinc was found in all tissues and organs examined, aluminum and manganese in practically all.

Prenatal Death

Death and resorption of the embryo during early pregnancy appears to be a far more common phenomenon than was once thought (67)(154). In a study of 49 Guernsey and 55 Holstein repeat-breeder cows the genitally normal cows with fertilized ova at three days were 66.1 percent, but at 34 days were 23.1 percent. This is an embryonic death rate of 65.1 percent (151). The results were summarized as follows (150):

(a) Failure of fertilization, 39.7 percent
(b) Embryonic abnormalities and embryonic death before 34th day, 39.2 percent
(c) Embryos still normal at 34 days, 21.1 percent

A study of 42 Holstein cows all bred at least four times without apparent conception showed that 88.5 percent were actually fertilized three days after breeding, but cows with normal embryos 34 days after breeding were only 26.7 percent (32). This is an embryonic death rate of 69.8 percent. Cows with Brahman breeding showed an embryonic death loss of 18 percent between 3 and 34 days, while cows without Brahman breeding under similar conditions had a 100 percent embryonic death loss for the same period (23). In sheep the embryonic death rate is placed at 32.7 percent of fertilized ova (47).

It has been estimated that 30 to 40 percent of all potential young in cattle are lost by 60 to 90 days after breeding (27)(91). There are maternal differences in this embryonic death rate (27), and evidence of a greater mortality of males during the intra-uterine development (84). Recent evidence as shown by erythrocyte mosaicism in a heifer recorded as single born indicates that prenatal mortality may occur in only one of a pair of twins (146). In the human, death of the fetus between the 6th and 17th week of pregnancy is not followed by emptying of the uterus at once, but as a rule the dead fetus and placenta are retained about six weeks (144).

Probable Factors in Prenatal Death

The quantitative and qualitative requirements for reproduction do not exceed those for growth of young animals or those for complete maintenance of mature animals (131). A deficiency of vitamin A has been shown to cause premature expulsion of the fetus, or the calves are weak at birth (63)(113)(62)(72). In order to support normal gestation, the carotene-blood plasma level of first-calf range Hereford heifers must be considerably higher than that for aged Hereford cows (122). Carotene-blood plasma level of first-calf range heifers must be 117.75 µg. per 100 ml. in order to support normal gestation. For aged cows 82.88 is sufficient. Vitamin A deficiency can be present in the calves although no visible symptoms are evident in the cows (8)(9). Since the thyroid is important in the conversion of carotene to vitamin A, a hypothyroid state combined with a low intake of vitamin A could result in abortion or dead or weak offspring (116).

In rabbits, of does were deprived of vitamin A fourteen weeks before mating, the offspring showed nervous disorders caused by hydrocephalus. In the rat, excessive intake of vitamin A caused an extrusion of the brain in many of the offspring (33).

Although there is a decided decrease in fertility of cows receiving a phosphorus-deficient diet, there is no apparent tendency for prenatal death or abortion (50)(101).

Test mice were exposed to a simulated altitude of 27,000 feet for five hours during the 9th or 15th day of gestation. Various congenital defects such as umbilical hernia and malformed ribs and vertebrae occurred (81). These defects occurred in strains in which the defects occasionally appeared under natural conditions.

In the northwest, pine needles and buds are a causative agent of abortion and the birth of weak calves. Pregnant range cows will consume quantities of the needles from western yellow pine even though they are adequately fed (112).

Control cows in which the corpora lutea were removed between the 92nd and 163rd day of pregnancy aborted promptly in the absence of progesterone replacement therapy (112). Intramuscular administration of 100 mg. of crystalline progesterone in sesame oil daily was necessary to maintain pregnancy in a high percentage of experimental cows.

Injections with large doses of F.S.H., especially in the presence of luteal tissue in the ovary, lead to too rapid passage of the ova down the tubes. Either the ova do not get fertilized, or if fertilized they pass to the uterus before it is in a properly receptive state and degenerate there. Degenerated, fertilized ova and early embryos have been found in heifers with quite normal reproductive tracts. Ova can be tube-locked by excess of estrogens and speeded down the tract by excess progesterone (68). In many cows there is a slight abnormality in the estrogen-progesterone level in the blood which causes such difficulties in conception.

The period of implantation is a critical period in the life of the embryo (94). Imperfect performance of the placentome can be the direct cause of prenatal mortality.

In a study with rats it was found that if an aged egg is penetrated by a spermatozoan, the female chromosomal mass may undergo relatively little pronuclear differentiation. The male element, on the other hand, may be transformed into the male pronucleus and its chromosomes may arrange themselves on a metaphase plate (14).

It has also been suggested that the death of fertilized ova may be associated with anomalies of the later stages of follicle maturation (103).

Pregnancy Tests

The palpation method appears to be most generally effective, especially from 35 to 49 days of gestation (167)(28).

No. of Days Pregnant	Discrepancy
30-60	15.3 percent
60-90	6.1 "
90-120	3.0 "

TABLE VI

Effect of Time of Insemination on Fertility in the Rat (14)

Time of Insemination	Percent Ova Fertilized	Percent Ova Abnormal
At ovulation	92	1.4
3-5 hours after ovulation	93	4
6-8 hours after ovulation	89	14
9-12 hours after ovulation	71	43

At least 4 percent of diagnosed pregnancies were lost before the end of four months. Viscous and elastic properties of bovine cervical secretions vary regularly during the estrous cycle. By means of a viscometer, pregnancy diagnoses were made. Accuracy is comparable with that obtained by rectal palpation (139)(140).

It has also been noted that estrous mucin has 1 to 1.5 percent dry matter, diestrous mucin 2 to 3 percent dry matter, and pregnancy mucin 4 to 5 percent dry matter. Pregnancy mucin does appear to react differently from estrous or diestrous mucus (17). As an example, solutions of H_2O_2 dissolve estrous mucin in three hours, diestrous mucin in one day, and pregnancy mucin in two days.

Pregnancy Tests

The Richardson biochemical pregnancy test has also been applied to dairy cattle (43). The test for humans utilizes 2, 4-dinitrophenylhydrazine in 95 percent ethanol to form a brown colored hydrazone with the estrone of pregnancy. In 400 trials with known pregnant cows, 194 reactions were negative. In 147 trials with open cows, 65 positive reactions were recorded. The test as applied is useless.

The colostrum pregnancy test was also used in cattle (26). It is an intradermal test, using colostrum as an antigen. The antigen is prepared by extracting colostrum from the breasts at about the seventh month of pregnancy. Pregnant women show little or no reaction to the material whereas nonpregnant women react rather vigorously, showing a characteristic wheal surrounded by a reddened area.

Bovine material was prepared in a similar manner. Injection was made inside the vulvar orifice. Results indicate that while there were marked differences in the responses of some animals to certain antigens, the test is not of sufficient accuracy in the bovine species to be used as a pregnancy test.

A test of Gavriljak's method has been reported (46). This method states that pregnancy can be diagnosed in cows 25 days after service by placing the hand lightly on the back in the region of the 9th and 13th vertebrae. Nonpregnant animals submit passively while pregnant cows resist and sometimes arch their backs. The test as applied by Gavriljak appeared to be very accurate, but the results could not be duplicated.

A measured quantity of faeces was mixed with water, filtered, and then injected into male toads. Sperm content of cloacal fluid was used as indication of pregnancy. Positive reactions were obtained from faecal extracts of nonpregnant cows, bulls, buffalos, horses, mares, and other animals. It was apparent that the animal feed was confounding the results since water extracts of grasses and other feeds produced a positive reaction in the toad. Since the reaction of the faeces is similar to the reaction produced by the food the animal eats, the faeces cannot be taken as test material for pregnancy diagnosis in animals (70).

The transverse folds which begin to appear on the surface of the vulva at about the fourth week of gestation are said to be characteristic of pregnancy and can be used as a means of diagnosis. The folding is most marked in the seventh and eighth week of pregnancy and disappears at four and one-half to five months; it is more easily detected during the first pregnancy than in later ones. Out of 1500 pregnant cows and 180 pregnant heifers, 95 and 96 percent, respectively, were correctly diagnosed as pregnant by the appearance of the vulva. Out of 120 nonpregnant cows and 40 nonpregnant heifers, 65 and 75 percent, respectively, were correctly diagnosed by this means (10).

		Gestation Length		
Breed	Ave. Both Sexes	Male	Female	Reference
Hereford		287.3	286.5	(135)
Hereford	285.2	285.0	285.2	(108)
Hereford		287.5	285.2	(56)
Hereford	286.3			(109)
Hereford	289.0			(136)
Hereford	283.4			(86)
Hereford	285.0			(161)
Hereford	286.1			(24)
Angus	282.5	282.7	282.2	(108)
Angus	276.4			(109)
Angus	272.8			(136)
Angus	280.9			(86)
Angus	279.0			(161)
Angus	281.7			(24)
Angus		277.2	275.7	(56)
Beef Shorthorn	280.8			(98)
Beef "	283.5			(86)
Beef "	281.0			(161)
Beef "	284.3			(24)
Dairy Shorthorn	285.6			(19)
Dairy "	281.7			(98)
Red Poll	285.0			(77)
Brazil Cattle	277.8			(123)
Jersey	280.44	281.04	279.86	(75)
Jersey	278.5			(38)
Jersey	277.9	278.6	277.2	(108)
Holstein	278.84	279.92	278.37	(75)
Holstein	279.9			(100)
Holstein	278.3	278.7	277.7	(108)

Breed	Ave. Both Sexes	Male	Female	Reference
Guernsey	283.5	284.0	282.9	(75)
Sussex	278.8			(42)
Ayrshire	277.8	278.1	277.5	(108)
Angus x Hereford	283.2			(109)
Angus x Hereford		283.1	283.5	(56)
Angus x Hereford	281.4			(136)
Hereford x Angus	282.0			(109)
Hereford x Angus	281.4			(136)
Hereford x Angus		282.7	281.1	(56)
Hereford x Brahman	286.0			(161)
Angus x Holstein	281.2			(35)
Holstein x Angus	277.6			(35)

Factors Affecting Length of Gestation

Sex: Bull calves tend to be carried longer than heifer calves (24)(109)(108)(38)(100)(75)(19)(135)(102). Although in many cases the actual difference was quite small, the bull calves were generally carried about one day longer than heifer calves (164)(18).

Breeds: There does appear to be a highly significant difference between some breeds. In most crosses, the F_1 animals tend to be intermediate to the parental breeds (35)(56).

Age of Dam: It is generally agreed that there is no consistent effect of age of cow on length of gestation (135)(42)(38)(18)(24), although a slightly longer gestation period has been reported for mature cows (100)(75). There also has been a reported tendency for individual cows to have a characteristic length of gestation (98), although this may not actually be statistically significant (24).

Sire: The sire of the fetus has been found to have a significant effect on the length of gestation (135)(161)(3)(18)(164). Sire effect has been reported as statistically nonsignificant (24).

Season: Conflicting results for the effect of season have been reported. Some investigators found that cows calving during the fall and winter carried their calves an average of one to three days longer than cows which calved during the spring and summer months (75)(135). On the other hand, a study of dairy cattle showed that gestations terminated by spring births are longest, and the shortest gestations preceded autumn births (18).

Other Factors:

(a) The average length of gestation for multiple births was somewhat less than the average for single births (75)(164). There was no significant difference between one-egg and other twins for length of gestation (44).

(b) Heavier cows tend to have longer gestation periods (18), although in some cases this difference may not be statistically significant (3).

(c) Length of gestation is unaffected by limiting sunlight and exercise (128).

(d) "Well fed" animals may have a slightly shorter gestation period than animals on a "maintenance" ration (80)(128).

(e) Cows 6 through 9 years of age, when bred to old bulls, showed a much larger number of calves carried *in utero* less than 282 days than did cows of those same ages when bred to young bulls.

Genetic: There is a positive correlation between the time the dam and her progeny spend *in utero* (18). It is generally agreed that the genotype of the calf is one of the more important factors in determining the length of the gestation period (3)(82). The genotype of the calf is responsible for about 48 percent of the total variance; the dam is responsible for about 21 percent.

Prolonged gestation due to genes carried by the fetus has been reported in Holstein and Swedish Red-and-White cows (60)(64)(83). Parturition may be delayed 20 to 88 days in the Holstein and up to 230 days in the Swedish Red-and-White.

Birth Weight

TABLE VII

Heritability of Birth Weight

Breed	Heritability	Method	Reference
Hereford	45	Paternal half-sib correlation	(59)
Hereford	100	Paternal half-sib correlation	(59)
Hereford	23	Intrasire correlation	(99)
Hereford	42	Sire-Offspring regression	(99)
Hereford	53	Half-sib correlation	(97)
Hereford	72	Paternal half-sib correlation	(142)
Beef Shorthorn	29	Paternal half-sib correlation	(40)
Milking Shorthorn	16	Paternal half-sib correlation	(41)
Hereford, Angus and Shorthorn	22	Paternal half-sib regression	(24)

TABLE VIII

Correlation of Birth Weight with Other Factors

Birth Weight Correlated with:	Correlation	Breed	Reference
Days from 500 to 900 lbs.	-0.28	Beef Shorthorn	(40)
Days from birth to 900 lbs.	-0.62	Beef Shorthorn	(40)
Efficiency	+ .13	Beef Shorthorn	(171)
Daily gain	+ .19*	Beef Shorthorn	(171)
Carcass grade	- .18*	Beef Shorthorn	(171)
Dressing percentage	- .13	Beef Shorthorn	(171)
Height at withers	+ .09	Beef Shorthorn	(171)
Height at floor of chest	+ .20*	Beef Shorthorn	(171)
Depth of chest	- .07	Beef Shorthorn	(171)
Width between eyes	- .05	Beef Shorthorn	(171)
Width at chest	- .20*	Beef Shorthorn	(171)
Daily gain, birth to weaning (Total population)	+ .34*	Hereford	(95)
Daily gain, birth to weaning (intrayear)	+ .32**	Hereford	(95)
Daily gain in feedlot (total population)	+ .30**	Hereford	(95)
Daily gain in feedlot (intrayear)	+ .47**	Hereford	(95)
Efficiency of gain in feedlot (Total population)	+ .23*	Hereford	(95)
Efficiency of gain in feedlot (intrayear)	+ .15	Hereford	(95)
Gain, birth to weaning (North Platte)	+ .07	Hereford	(59)
Gain, birth to weaning (Valentine)	+ .44**	Hereford	(59)
Weaning weight (North Platte)	+ .27**	Hereford	(59)
Weaning weight (Valentine)	+ .60**	Hereford	(59)

Factors affecting Birth Weight

Length of Gestation: Cows with longer gestation produced calves heavier at birth (135)(25)(24)(19). The regression of birth weight on gestation length has been reported as + 0.376 (24), and as 0.9. Continual growth of the fetus in prolonged gestation also has been noted (83)(64)(60).

An orderly relation has been found between the heat increment of gestation and the birth weight of the offspring (21). The production of an offspring weighing 1 kg. at birth is associated with a gestation heat increment of about 4400 calories, and the magnitude of this increment varies with approximately the 1.2 power of the birth weight of the offspring.

Age of Dam: Age of dam has been reported to influence the birth weight of the calf. It is generally agreed that calves from two-year-old heifers are generally quite small and there is a tendency for older cows to have heavier calves. A regression of birth weight of the calf on age of dam of +1.043 lbs. has been reported, with the maximum birth weight not reached until the cows are nine to ten years of age (24). However, the results generally indicate that the heaviest calves come from cows six to eight years of age with a gradual reduction in birth weight for older females (157)(19)(40). In Herefords, the first calf will average five to eight pounds lighter at birth than the calf from a mature cow (96)(135)(170).

Weight of Dam: While a cow is growing, her consecutive calves increase in size (19). Since age of cow and weight of cow are closely associated during this period, it is not always possible to accurately separate the effects of age of dam and weight of dam on birth weight of the calf. When comparisons are made between types of cattle, significant differences are apparent (170). Within a type, age of dam and weight of dam may be considered to have similar effects on birth weight of the calf. The nutrition of the cow does not have an appreciable influence on the size of the calf at birth (49a). Cows which maintain a higher condition throughout gestation are more likely to produce lighter calves, although this may be associated with length of gestation (128).

Sex: Male calves are heavier at birth than female calves. Differences in favor of the male have been reported as 3 lbs. (123), 1.3 lbs. (109), 2.3 lbs. (135), 3.9 lbs. (194a), and 3.5 lbs. (49a). Similar results are shown in average birth weight values for male and female calves (96)(30). The sex difference is apparently significant and the variability is due to differences between breeds as well as other confounding factors.

Breed: In dairy cattle, there is a significant difference between various breeds in birth weight (49a). There appears to be a great deal of variation in the reported birth weights of the various breeds of beef cattle. The reported data for birth weights is generally uncorrected and in some cases includes weights for several years. These data can at best serve only as a guide, and cannot be used as actual values for breed differences. In some cases, the differences in birth weight can be generally accounted for by differences in the length of gestation (56). There does appear to be a pattern of increased birth weight for crossbred calves, but the differences are often quite small. Differences between bulls within the same breed appear to be important in the results of breed crosses (31).

The difference between types within a breed may be more extreme than differences between breeds. The comparison of large and small type Hereford cattle showed the following differences in birth weight (170):

Type	Average Birth Weight (Both Sexes)
Small	65.5 lbs.
Large	72.5 lbs.

TABLE IX

Reported Birth Weights of Beef Breeds and Breed Crosses

Breed	Sex	Ave. Birth Weight (lbs.)	Reference
Angus	Both	69.9	(141)
Angus		60.1	(134)
Angus	M	67.1	(25)
Angus	M	64.0	(4)
Angus	F	61.8	(25)
Angus	F	56.0	(4)
Hereford	M	75.0	(59)
Hereford	F	70.0	(59)
Hereford	M	67.4	(25)
Hereford	F	65.4	(25)
Hereford	Both	75.4	(111)
Hereford (heifers)	M	66.0	(31)
Hereford (heifers)	F	59.0	(31)
Hereford	F	73.0	(170)
Hereford	Both	75.0	(13)
Hereford		75.0	(133)
Hereford	Both	73.0	(135)
Hereford	M	76.9	(96)
Hereford	F	71.1	(96)
Hereford	F	74.1	(5)
Shorthorn	M	66.7	(24)
Shorthorn	F	61.8	(24)
Shorthorn	Both	69.2	(99)
Milking Shorthorn	Both	79.2	(99)
Brazil Cattle	M	88.0	(123)
Brazil Cattle	F	81.4	(123)
Angus x Hereford (heifers)	M	68.0	(31)
Angus x Hereford (heifers)	F	62.0	(31)
Hereford x Shorthorn	F	77.1	(5)
Brahman x Hereford	Both	74.6	(111)
Brahman x Hereford		75.0	(133)
Hereford x (Brahman x Hereford)		76.0	(133)
Hereford x (Brahman x Hereford)		69.1	(111)
(Hereford x Brahman) x Hereford		83.0	(133)
Angus x Arkansas Native	Both	61.5	(141)
Angus x Mississippi Native	Both	64.0	(160)
Polled Devon x Mississippi Native	Both	64.0	(160)
Polled Shorthorn x Mississippi Native	Both	66.0	(160)
Polled Hereford x Mississippi Native	Both	67.0	(160)
Native Mississippi x Native Mississippi	Both	62.0	(160)
Native Arkansas x Native Arkansas	Both	64.2	(141)
Brahman x Angus	F	66.0	(4)
Angus x (Brahman x Angus)	F	62.0	(4)
(Brahman x Angus) x Angus	F	63.0	(4)
(Brahman x Angus) x (Brahman x Angus)	F	62.0	(4)
Africander x Angus	F	64.0	(4)
(Africander x Angus) x (Africander x Angus)	F	64.0	(4)

Breed	Sex	Ave. Birth Weight (lbs.)	Reference
Brahman x Angus	M	71.0	(4)
Angus x (Brahman x Angus)	M	62.0	(4)
Africander x Angus	M	70.0	(4)
Zebu		78.1	(134)
Africander		70.8	(134)
Zebu x Africander		72.8	(134)

Other Factors:

(a) There was no significant difference in the birth weights between calves sired by the same bulls at two different stations (169).

(b) Sire differences were negligible for birth weights (95).

(c) The repeatability of birth weight is about +0.20 (59).

(d) There is no significant difference in birth weights of calves from full- or limited-fed cows (170). Similar results have been found with protein supplementation (13). Studies with sheep show no effect on birth weight of single lambs if ewes were on a high or low plane of nutrition (121).

(e) The repeatability of cow performance for birth weight has been determined for three different herds (143).

Herd	Intraclass Correlation	Correlation of Adjacent Calves
Oak Ridge	.30	.25
Greenville	.01	.01
Crossville	.03	-.01

TABLE X

Birth Measurements (149) (in inches) of Dairy Shorthorn Calves

Measurement	Heifer Calves Mean	Heifer Calves S.D.	Bull Calves Mean	Bull Calves S.D.
Length of body	21.93	0.98	22.39	1.01
Length of hindquarter	8.50	0.49	8.64	0.74
Height at withers	28.23	1.18	28.78	1.18
Height at hooks	29.39	1.12	29.89	0.94
Depth of chest	10.93	0.61	11.20	0.65
Width of chest	7.27	0.12	7.49	0.60
Width at hooks	6.90	0.45	7.13	0.48
Width at pin bones	4.47	0.29	4.49	0.40
Girth of chest	29.54	1.15	30.13	1.42
Circumference of foreleg	4.36	0.24	4.67	0.28
Length of head	9.37	0.51	9.49	0.51
Width of head	5.66	0.40	5.88	0.43
Circumference of muzzle	8.82	0.50	8.90	0.44

At birth the hypophysis is about .45 gm. for females and .5 gm. for males, although the range is from .3 to .7 gm. for females and .4 to .8 gm. for males (57). There is no apparent relationship between the relative hypophysis weight and producing ability.

Allometric growth of the forelimb has been studied in five breeds of cattle (125)(126). Growth of the forelimb exhibits throughout the whole or greater part of postnatal development simple negative allometry relative to the growth of the trunk. If the moment of postnatal allometry is near the time of birth, size of limbs and body in newborn calves may be important factors in size and proportions in later life.

Sex Ratio

The primary sex ratio in mammals is the number of males per 100 females at conception. The secondary sex ratio is the number of males per 100 females at birth (154).

The primary sex ratio in cattle has been reported as 123.21 (84). A review of the secondary sex ratio in cattle listed the results by different authors as 107.3; 106.3; 100.2; 94.4 (106). In a study of 124,000 cattle births in Sweden, the secondary sex ratio was 106.2 (85). In the semiarid regions of South Africa the ratio is 106 (138). Observations with dairy cattle indicate that the distribution of sexes in cattle families is essentially at random (58).

Factors affecting Sex Ratio

Age of Parents: The age of the sire or dam does not materially affect the sex of its progeny (58)(85)(78).

Season: There is no evidence that season influenced the sex ratio of offspring (106)(78).

Sire: There is evidence of a sire effect on the sex ratio of the offspring (89). In comparing natural breeding to artificial insemination, the sex ratio in natural breeding was 96.8 and 106.8 for artificial insemination. However, the difference was due to the unequal ratios of specific bulls used under both conditions and not to the method of breeding.

Fetal Mortality: The sex ratio during fetal development in cattle is 123.21. This sex ratio compared with lower sex ratios at birth indicates a greater mortality of males during intra-uterine development. The data now available indicate that there is no particular stage in development during which there is more marked mortality among males than in any other stage (84).

Other Factors:

(a) There was no indication that breed causes any variation in the sex ratio (84).

(b) In cattle the sex ratio was unaffected by time of service (106).

(c) In humans size of the sperm head has been noted as related to abnormal sex ratios (145).

(d) In rabbits the sex ratio is affected by the number of times of service on the part of the male, there being a predominance of males in the first service group and then usually an increasing predominance of females as the number of services is increased (88):

	Service				
	1st	5th	10th	15th	20th
Sex ratio	112.7	87.0	89.0	69.2	43.8

Either the female-producing spermatozoa are produced more largely than male-producing spermatozoa as the amount of service of the male increases or the male-producing sperm are in themselves weaker than the female-producing sperm and, consequently, fewer of them survive to take part in fertilization.

(e) In humans a strong relationship has been found between the occupation of fathers and the sex ratio of offspring (12). The more masculine the occupation of the father, the higher the percentage of sons.

Parental Occupation Classification	Percentage of Sons
Women in masculine occupation	56.6
Women in feminine occupation	50.2
Both parents in masculine occupation	58.3
Both parents in feminine occupation	46.2
Father in masculine occupation and mother in feminine occupation	51.87
Father in feminine occupation and mother in masculine occupation	51.4

The differences between these groups are statistically significant. This difference is associated with the relative strength of feminine and masculine genes.

(f) In a study of the effects of selection on the sex ratio in rats, it was found that heritable factors were involved (92). The normal sex ratio is 105 males per 100 females. Selection from litters with more males resulted in inbred lines with an average of 118 males for 100 females. It was concluded that heritable factors act on the metabolism of ova in such a way as to render the ova more easily fertilized by one kind of spermatozoa than another.

Multiple Births

In beef cattle, estimates of the frequency of multiple births have been determined from breed herdbooks.

In dairy cattle the frequency of twin births has been estimated as about one percent (110), although 1.5 percent and 1.9 percent also have been reported for specific areas (75)(90). The incidence of multiple ovulations for dairy cattle has been placed at 13.1 percent (90). There appears to be a seasonal variation in multiple ovulation with a high in May and a low in September.

TABLE XI

Frequency of Multiple Births; Number of Single Births for Each Multiple Birth

Breed	Kind of Multiple Birth	Frequency	Reference
Angus	Twin	1:332	(37)
Angus	Twin	1:243	(87)
Hereford	Twin	1:221	(87)
Hereford	Twin	1:219	(37)
Hereford and Angus	Twin	1:213	(36)
Angus	Triplet	1:109,600	(87)
Angus	Triplet	1:149,600	(37)
Hereford	Triplet	1:104,180	(37)
Hereford	Triplet	1:105,580	(87)
Hereford and Angus	Triplet	1:107,200	(36)
Hereford	Quadruplet	1:520,900	(37)

In beef cattle, a peak of twin births has been noted for August, with a low point in March (36).

A study of Angus and Hereford herdbooks has shown an association of twin births with age of the dam (128). The records show that there is a rapid rise in the frequency of twin births to about five years of age, followed by a gradual rise to 15 or 17 years of age.

There is evidence that hereditary factors are involved in the high incidence of twinning in some families (74)(85)(110), although the exact mode of inheritance has not been determined. Except for isolated families there is no evidence that twinning is inherited (44).

Monozygotic Twins

The identification of monozygotic twins is of value if such animals are wanted for research. The fetal attachments of bovine twins give the embryos a common circulation and, therefore, identical results when tested for inherited cellular antigens (120). However, it is still possible to distinguish like-sexed dizygotic twins that differ in one or more antigenic components by a quantitative test (147). Muzzle prints show that monozygotic twins are more alike than dizygotic twins, but in general this method is not accurate enough for differentiation (163). Thickness, structure, and shape of cross-sectioned hairs appear to be quite differentiating (15).

A summary of visible characters to use in differentiation shows that the main points to check are (69):

(a) Hair color: The color of some hair growths, such as eyelashes, ear fringes and tail swish is not obscured by birth coat color and is particularly useful for comparison.

(b) White markings: Apart from the need for a general similarity in pattern, white color markings are not a good criteria for identification.

(c) Whorls: Similarity or dissimilarity of hair whorls is not a good criterion since identical twins may show quite large variation in hair whorl.

(d) Size and body conformation: Even small differences in head form will be a strong indication that the calves are not identical.

(e) Ears: Ear color patterns are very useful in identifying identical twins.

Parturition

Normally, losses at birth are considered to be associated with a disease or an inherited defect which is lethal. Losses in cattle due to brucellosis, leptospirosis, and vibriosis in the United States are estimated to be in excess of $275,000,000 annually (153). Inherited factors such as dwarfism (61) and dropsical calves (45) can be important considerations in calf losses.

The feasibility of breeding yearling heifers to calve as two-year-olds has received considerable attention lately. Under range conditions, only about 65 percent of the yearling heifers will become pregnant (11). It has been estimated that 25 to 60 percent of the heifers require help at calving (32)(33)(168), although the three-year-old heifers may require as much assistance as two-year-olds (127). In a study of 2,545 heifer calvings, about

2 percent of the heifers died while calving (1). The postnatal death loss appears to be no greater with first calves compared to later ones, although the prenatal loss is greater for first calves (168). The factors which may influence the results of heifer calving are as follows:

(a) Use young, small-bodied, small-boned bulls (1).

(b) Individuality of the bull is involved but not always directly associated with size (31).

(c) Individuality of the bull may be more important than the breed of the bull (31).

(d) The size of the heifers at calving is important. Heifers should be well grown out by calving (11)(1).

TABLE XII

Relation of Weight of Heifers to Calving Performance (31)

	Weight of Heifers at Breeding		
	Over 500	450-500	Below 450
No. of heifers requiring help	5	8	9
No. of heifers calving normally	12	7	5

(e) Feed heifers for continuous growth (1).

(f) There are fewer losses of crossbred calves at birth or as young calves (56).

Inbreeding in Jersey and Holstein cattle has shown that the number of stillbirths tends to increase with inbreeding (129). Inbred calves with extremes in birth weight, either high or low, succumb more readily than calves near the mean weight (130).

The nutrition of the dam during pregnancy is of secondary importance compared to climate and care in the viability of calves at birth (168). The amount of nutrients necessary to develop the bovine fetus is so small that it cannot be measured by ordinary methods (49).

The effects of nutrition can be seen in extreme conditions. Under conditions of environmental stress, chronic undernourishment in the unadapted types can be detected even in newly born calves (16). The calves born after a summer gestation are 20 percent lighter than calves of the same animals born after a winter gestation. Manifestations of an extreme vitamin A deficiency in cattle are premature expulsion of the fetus and severe diarrhea in newborn calves (63) or the birth of dead or weak calves (72)(62). Beef cows receiving a carotene allowance equivalent to 60 µg. per pound of body weight daily were unable to maintain liver stores or plasma vitamin A levels during the last six months of gestation. When the carotene allowance was increased to 333 µg. liver stores and plasma vitamin A were increased (6). However, under usual range management procedures the vitamin A is apparently adequate for normal gestation and parturition (158). Normal vitamin A levels of blood plasma for newborn calves is about 4 µg. per 100 ml. of plasma (7), and 6 I.U. vitamin A per gm. of liver (20). Feeding pellets containing 125,000 I.U. vitamin A, 25,000 I.U. vitamin D and 250 mg. of niacin was of no value in reducing colds, pneumonia, scours, and death losses of newborn calves under a wide variety of conditions (51). Vitamin E deficiency has caused serious losses in Maine (79).

TABLE XIII

Blood Erythrocyte Values. R.B.C. Count (millions per cubic mm. blood) (2)

Fetus at Fraction of Term	Value	Range
.3	3.9	3.7 - 4.1
.4	4.8	4.5 - 5.3
.5	4.8	3.8 - 5.5
.6	5.5	4.4 - 6.4
.7	5.2	4.2 - 6.2
.8	5.9	5.4 - 8.0
.9	6.1	5.9 - 6.2
Term	6.8	6.0 - 7.8

TABLE XIV

Hematocrit (ml./100 ml. blood) (2)

Fetus at Fraction of Term	Value	Range
.3	37.7	34 - 40
.4	43.0	40 - 47
.5	36.7	28 - 45
.6	40.4	32 - 50
.7	37.0	32 - 44
.8	39.7	35 - 47
.9	31.0	30 - 32
Term	35.9	32 - 42

TABLE XV

Blood Hemoglobin Concentration (g./100 ml. blood) (2)

Fetus at Fraction of Term	Value	Range
.3	8.5	7.7 - 9.1
.4	10.9	10.3 - 11.4
.5	8.5	6.9 - 9.7
.6	9.6	7.7 - 11.2
.7	9.7	8.3 - 12.1
.8	9.8	8.8 - 11.5
.9	8.4	8.3 - 8.5
Term	9.6	8.5 - 10.8

TABLE XVI

Corpuscle Hemoglobin Content ($\mu\mu g.$) (2)

Fetus at Fraction of Term	Value	Range
.3	21.3	20.5 - 22.0
.4	21.1	20.0 - 21.6
.5	18.6	17.5 - 20.2
.6	17.5	17.4 - 17.6
.7	18.6	16.5 - 19.6
.8	15.0	14.3 - 16.2
.9	13.9	13.4 - 14.3
Term	14.1	13.7 - 14.5

TABLE XVII

Corpuscle Volume (μ^3)

Fetus at Fraction of Term	Value	Range
.3	93	91 - 97
.4	88	84 - 89
.5	77	74 - 83
.6	74	71 - 77
.7	71	79 - 75
.8	57	58 - 63
.9	51	49 - 53
Term	53	50 - 54

TABLE XVIII

Estrogen as Estradiol. Pregnant Cow (2)

0.38 µg./100 ml. blood
0.2 µg./100 ml. R.B.C.
0.1 µg./100 ml. plasma

TABLE XIX

Blood Glutathione of Newborn Calves (132)

	Glutathione (mg. %)		
	Reduced	Oxidized	Total
Bull Calves	55.53	6.09	61.62
Heifer Calves	57.19	8.07	65.26
Calves	56.36	7.08	63.44

TABLE XX

Blood Glucose and Acetone Bodies of Normal Animals (107)

	mg./100 ml. Blood
Before parturition	
Blood glucose	47
Blood acetone bodies	2.7
Postpartum	
Blood glucose	41
Blood acetone bodies	6.3

TABLE XXI

Vitamin A and Carotene Content of the Blood of Pregnant Cows and Newborn Calves (9)

Item	5 Months Prepartum	1 Month Prepartum	At Parturition
Cows:			
Plasma vitamin A	32.5	25.0	17.3
Plasma carotene	111.6	22.9	21.3
Milk and colostrum vitamin A			144.0
Calves:			
Plasma vitamin A			4.9

TABLE XXII

Summary of Trace Elements in Tissues of Newborn Calves (ppm. of dry matter) (137)

TISSUE	Al	Ba	B	Cr	Co	Pb	Mn	Mo	Ag	Sr	Sn	Ti	V	Zn	Ni
Liver	0-.6	0-.6	0	0	0-.6	.4-29	2.4-29	.6-4.6	0-.6	0-.6	0	0	0	38-475	0-3.8
Kidneys	0-2	0-.6	0-18	0-.6	0-.6	.5-6	.5-5.8	.4-18	0-.6	0-.6	0	0	0	46-194	0-3
Heart	0-.5	0-.5	0-5	0	0	0-5	.4-3.6	0-.5	0-.4	0-.5	0	0	0	36-162	0-1.6
Pancreas	0-.5	0-.5	0-1.5	0	0-3.6	.1-4.5	.1-5.6	.1-2.8	0-.5	0-.6	0-.6	0	0	2.8-53	0-5.6
Lungs	T-.6	0-.6	0-3	0	0	0-.6	.4-1.8	.4-1.8	0	0-.6	0	0	0	39-146	0-.6
Spleen	0-19	0-.6	0-33	0-2	0-6	0-18	.5-3	.5-2	0-.6	0-.6	0-6	0	0	48-189	0-6
Thymus	0-7	0-.8	0-2	0-.8	0	0-3	0-2.4	0	0-.8	0-.8	0-2	0	0	43-240	0-.8
Flesh	0-14	0-.6	0	0-5	0	T-2	.5-4	0	0	0-.6	0	0	0	48-57	0-4
Brain	0-104	0-.9	0	0-30	0	0-.7	.4-29	0-.7	0	0-.9	0	0	0	28-293	0
Rib	0-5	.5-17	0-14	0-.5	0	0-5.7	0-14	0	0	4-18	0	0	0	14-438	0
Adrenals	.5-2	0-.7	0-2	.5-6	0-.7	.7-5	.5-5	.6-.7	.7	0-.7	0-.7	0	0	54-202	.5-2
Gallbladder	.5-10	0-.9	0	0-5	0	0-1.5	0-4	0-5.3	0-.5	0-.8	0	0	0	47-98	0-16
Pituitary	0	0	--	0	0	0-5	.4-1	0	0-.5	0	0	0	0	--	0
Blood	.3-.7	0-.4	0-3	0	0	0-.4	0-2	0	0	.4-.7	0	0	0	3-23	0
Thyroid	.4-1	0	--	.3-.5	0	.3-1	.3-1	.3-.5	T-.3	0	0	0	0	--	0-1
Testes	0-.7	0	.4-2	0-.5	0	0-2	.4-2	0-.6	0-.6	0	0	0	0	45-169	0
Urine	0-T	0-T	7-177	0-21	0	0	0	1-7	0	0-2	0	0	0	5-14	0-7
Vertebra	0	T-15	0	0	0	0-T	0	0	0	T-15	0	0-4	0	3-12	0
Bone Marrow	0	2-15	0	0-40	0	0	0-25	0	0	1-15	0-.3	0	0	10-250	0
Skin	21-77	.2-38	.6-23	.2-23	4-21	2-77	1-23	.2-18	0-2	.2-2	0-38	.2-38	0	10-77	1-23
Fat	T-.3	0-.6	0	T	0-.2	.5-2	T-.6	0-T	T	0-T	0	0	0	6-22	T-.2
Hair	17-38	.1-11	.8-11	.6-29	.3-6	13-111	.2-29	0-1	T-.6	.6-3	.4-2	13-58	0-.4	13-58	.4-8

TABLE XXIII

Summary of Various Tissues and Organs in Newborn Calf (137)

Tissue	Total Fresh Weight	Total Dry Matter	Total Ash	Moisture
	grams	grams	grams	percent
Pituitary	0.3544	0.0787	0.0033	77.79
Thyroid	4.0036	0.8727	0.0410	78.20
Thymus	80.0	22.92	1.9973	71.34
Adrenals	2.4031	0.4715	0.0310	80.38
Testes	3.8684	0.6429	0.0432	83.38
Brain	196.67	71.675	2.5068	63.55
Heart	147.37	31.457	1.5376	78.65
Blood	1,279.12	214.457	1.5376	83.22
Lung	274.45	62.895	3.07	77.08
Kidney	73.08	18.050	0.8967	75.30
Urine	248.42	4.5023	0.7966	98.18
Pancreas	11.7022	2.8623	0.1429	75.54
Spleen	42.64	10.620	0.6707	75.09
Vertebra	292.0	132.064	51.038	55.08
Skull and Jaw	468.0	264.560	162.765	43.47
Flesh	6,878.0	1,609.130	77.772	76.94
Skin	2,255.0	521.580	11.292	76.87
Fat	353.0	230.827	1.4756	34.61

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